Beyond Standard Model searches in ultraperipheral heavy-ion collisions with ATLAS

Agnieszka Ogrodnik (AGH UST), on behalf of the ATLAS Collaboration

Ultraperipheral heavy-ion collisions

- Photon-photon interactions can be observed in ultraperipheral heavy-ion collisions at the LHC due to large EM fields associated with relativistic ions (cross-sections scale with $\sim 1/r^2$).
- Advantages: low hadronic pileup, possibility of lower trigger thresholds.
- EM field is treated as a beam of quasi-real photons with small virtuality (equivalent photon approximation).
- The EM interactions are dominant for impact parameters larger than 2rf.
- Incoming photon fluxes are studied in detail with exclusive dilepton production measurements [1,2].
- Possibility to study rare processes:
  - light-by-light (LbyL) scattering [3-5].
  - Exclusive diatup production in semi-/fully-leptonic decay channels [6].
  - Exotic hadron production search proposed [7].

$\alpha_s$ - measurement strategy

- Signal $\tau$-leptons are low-energetic, typically with $p_T < 10$ GeV.
- No standard ATLAS identification of $\tau$-leptons is used.
- Instead events classified based on the charged $\tau$-lepton decay products.
- Three signal categories:
  - $\mu$ + 1 track.
  - $\mu$ + 3 tracks, $\mu$ + $e$.
- Single muon trigger used to record signal events with muon $p_T > 4$ GeV.
- Exclusivity requirements: veto on additional tracks, low-$p_T$ clusters, and forward neutron activity (using T0n configuration based on ZDC signal).
- Main background contributions from dimuon production and diffractive photonuclear interactions.
- Dimuon control region ($\tau \rightarrow \mu \mu$ events) used to reduce systematic uncertainty from the photon flux.

$\alpha_s$ - results

- The $\alpha_s$ value is extracted using a profile likelihood fit using the muon $p_T$ distribution.
- Simultaneous fit combining all signal regions and dimuon control region.
- Calculations are based on the same parameterization as was used in previous LEP measurements.
- Approximately 80 nuisance parameters (statistical and systematic uncertainties) are included in the fit.
- Many of them correlated between signal and control region.
- The best fit value is $\alpha_s = -0.042$, with the corresponding 95% CL interval being $(-0.058, -0.012)\cup (0.006, 0.025)$.
- The result is largely limited by statistics.
- Constraints similar to DELPHI [11].

ALPs - $\gamma\gamma \rightarrow \gamma\gamma$ event selection

- The signature is: two low-ET, back-to-back photons without any additional activity in the detector.
- Dedicated diphoton trigger was developed.
- New photon identification procedure based on neural network was developed and optimized for low-ET photons.
- Fiducial selection: two photons each with transverse energy $E_T > 2.5$ GeV, pseudorapidity $|\eta| < 2.37$, diphoton invariant mass $m_{\gamma\gamma} > 5$ GeV, diphoton transverse momentum below 1 GeV.
- Background suppression by requiring no additional tracks and diphoton acoplanarity ($\gamma\gamma$) below 0.01.
- Background sources from $\gamma\gamma \rightarrow e^+e^-$ and Central Exclusive Production (CEP) are estimated using data-driven techniques.

ALPs - methodology

- Events for the ALP signal were generated using Starlight MC generator for various ALP masses ($m_a$) ranging between 5 and 100 GeV.
- The search is performed using $m_{\gamma\gamma}$ distribution.
- Simulated LbyL events are normalized to the data yield, after subtracting $\gamma\gamma \rightarrow e^+e^-$ and CEP $\gamma\gamma \rightarrow \gamma\gamma$ contributions and excluding the mass search region.

ALPs - results

- ALP contribution is fitted individually for every mass bin using a maximum-likelihood fit.
- No significant deviation from the Standard Model background-only hypothesis is observed.
- The result is used to estimate the upper limit on the ALP cross-section and ALP coupling $1/\alpha_s$ at 95% confidence level.
- The obtained exclusion limits are the strongest so far for the mass range of $6 < m_a < 100$ GeV.

This work was partially supported by PL-GRID infrastructure, 2020/16/T/ST2/00086 and 2020/37/B/ST2/01043 grants.

References:
[10] PLB 809 (2020) 135682
[12] DELPHI 2004